

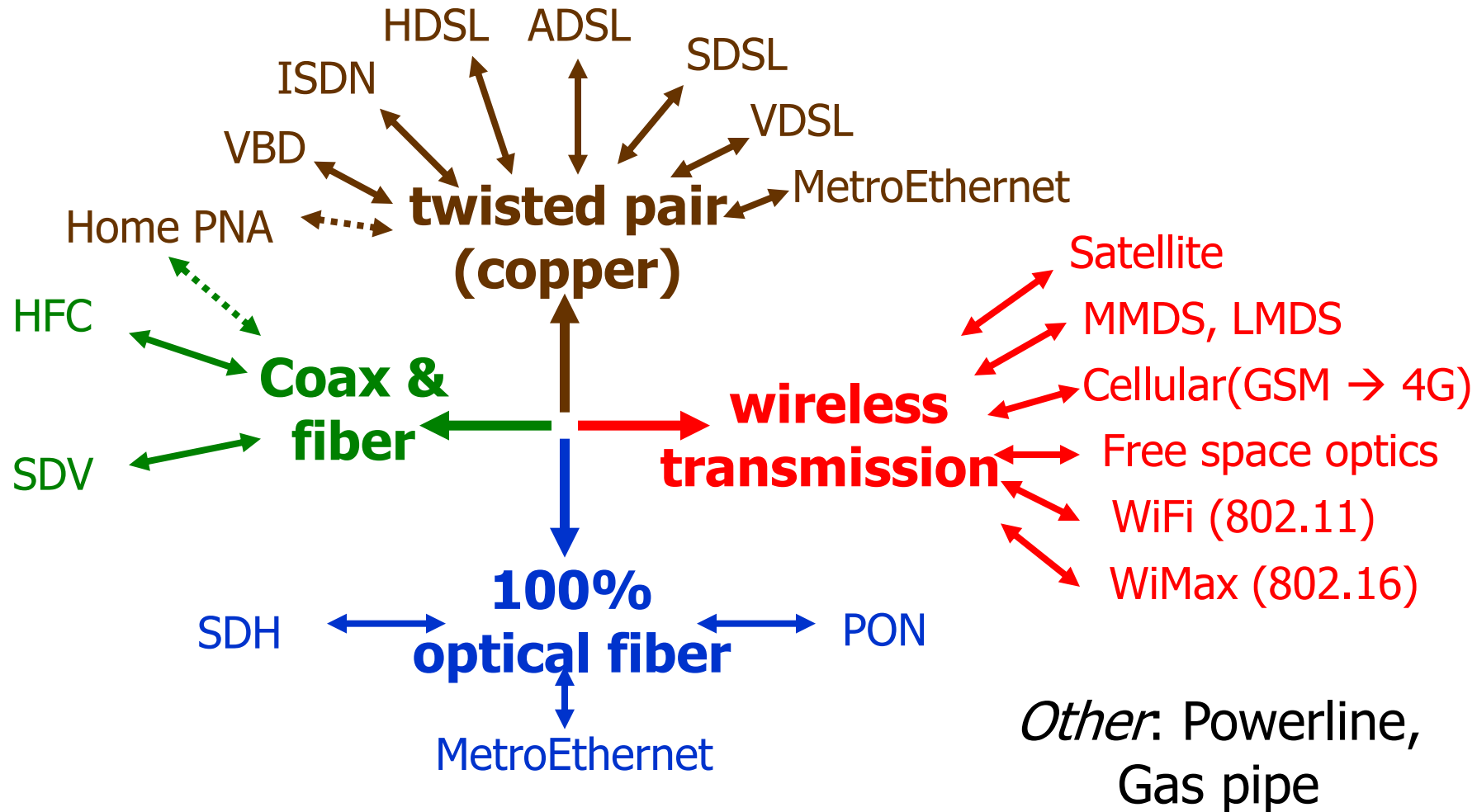
Broadband (III): Wireless access

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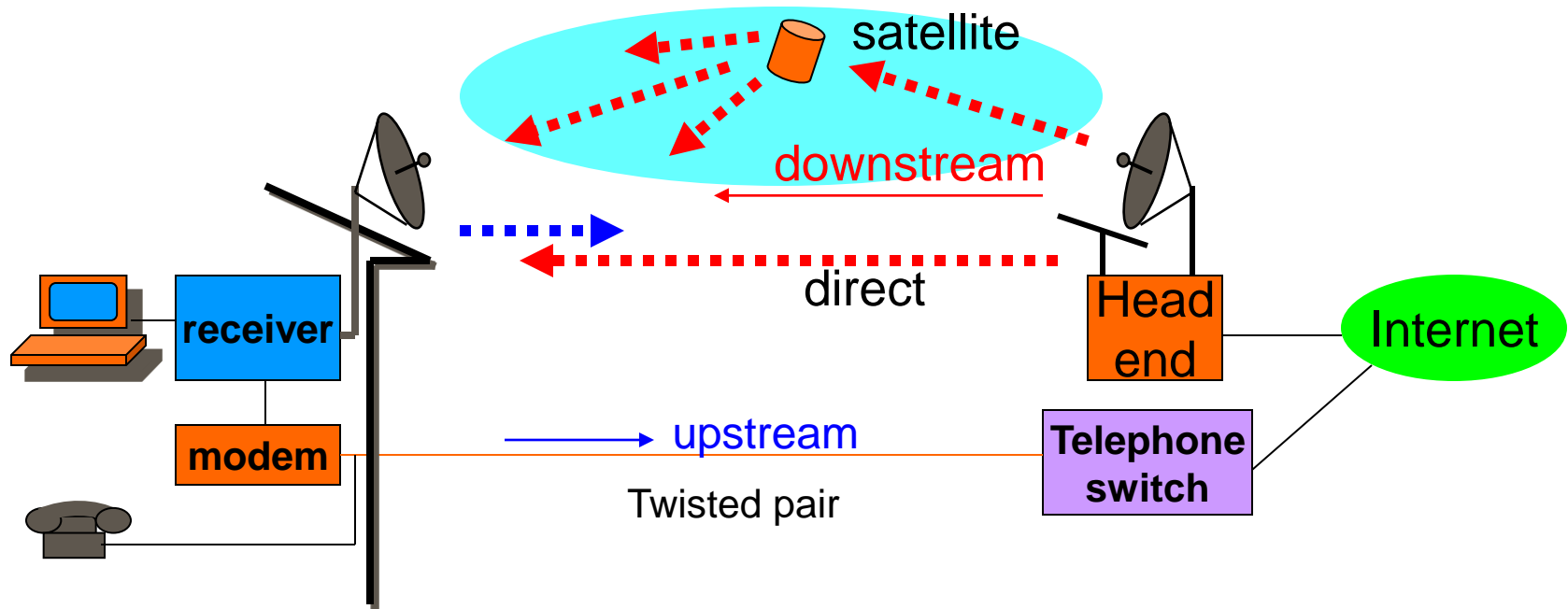
Spring 2011

Basic access technologies



Wireless access technologies

Wireless access to Internet (early steps)

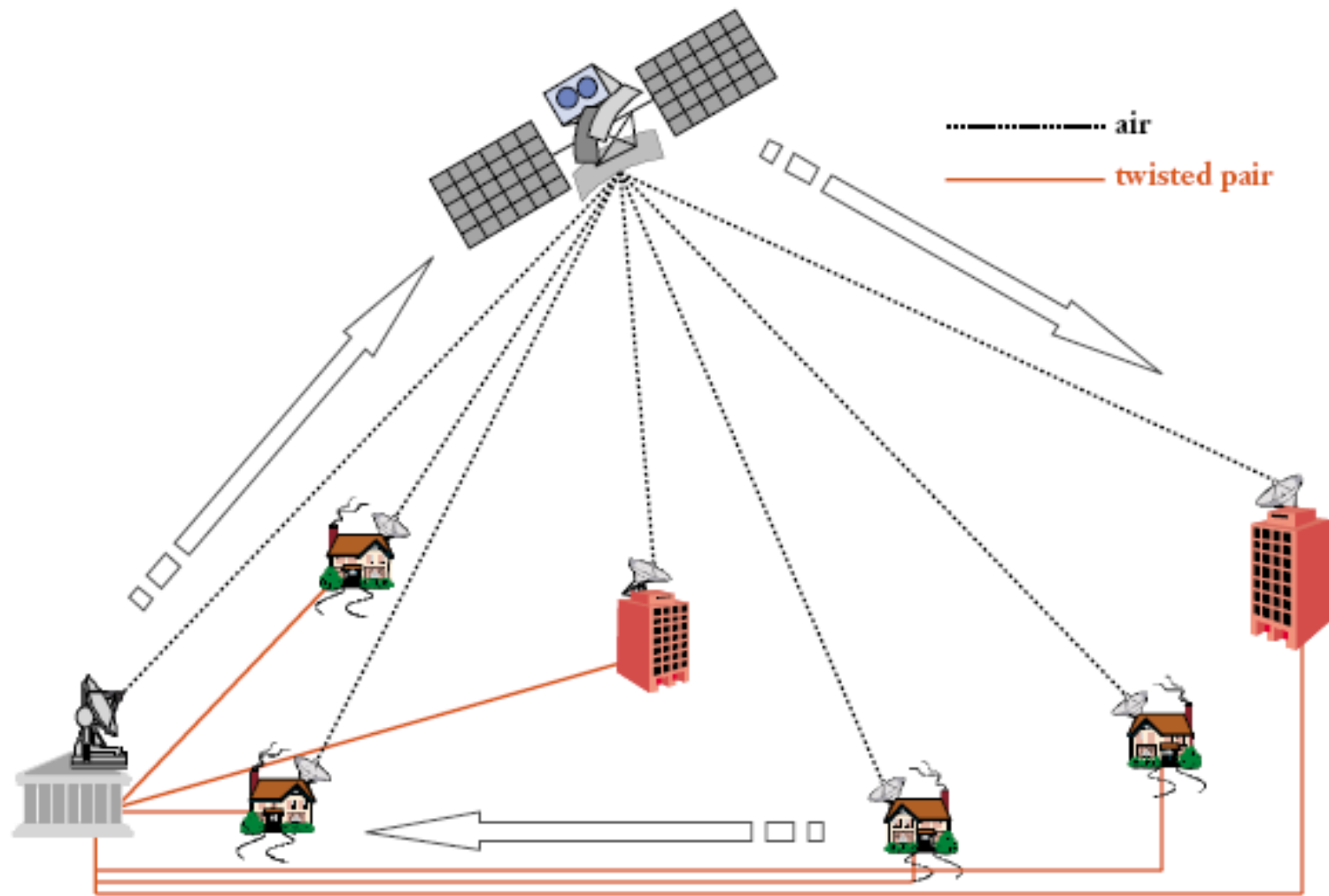


- Cellular: voiceband modems, 9.6kbps, CDPD = 19.2kbps
- Terrestrial broadcast: MMDS and LMDS
- Direct Satellite Broadcast (DBS):
 - down link 400kbps - 1Mbps, possibly bidirectional

Broadband over Satellite

- Three types of Internet service:
 - One-way broadcast (like TV)
 - One-way plus terrestrial return over dial-up
 - Down-channel rate may reach 24 Mbps
 - Two-way, with very small aperture antenna
- Available worldwide, yet more suitable for:
 - Remote and sparsely populated areas
 - Broadcast applications, due to:
 - high propagation delay
 - high cost of two-way capable customer's antenna

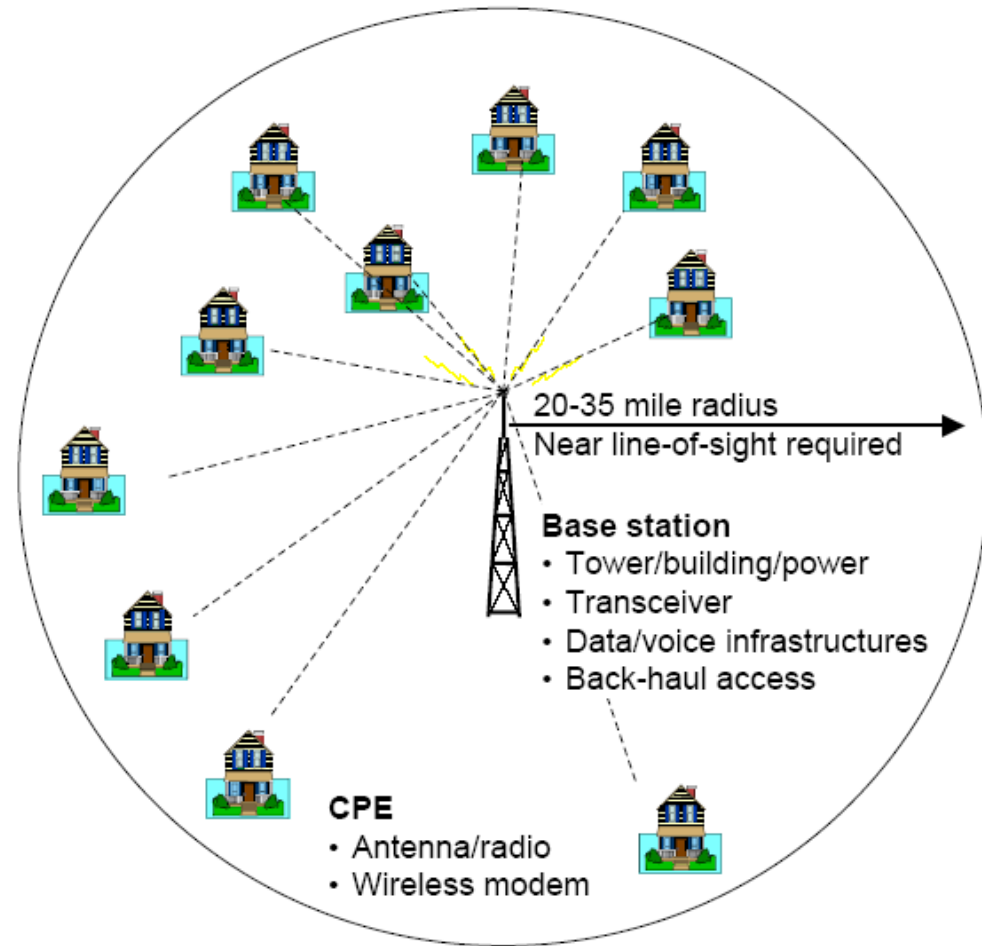
Broadband over Satellite architecture, with Terrestrial Return



Source: © Corning

MMDS (I)

- **Multichannel Multipoint Distribution Services (a.k.a. wireless cable network)**
 - Multichannel: multiple spectral bands, allocated in 6 MHz channels
 - 10-27Mbps of shared capacity per channel
 - Multipoint: bandwidth is shared among end-users
 - Distribution Services: initially used as a cableTV substitute
- Several multiplexing options
 - FDMA, TDMA, CDMA, OFDM
- Cell splitting increases capacity by reusing spectrum (scalability)

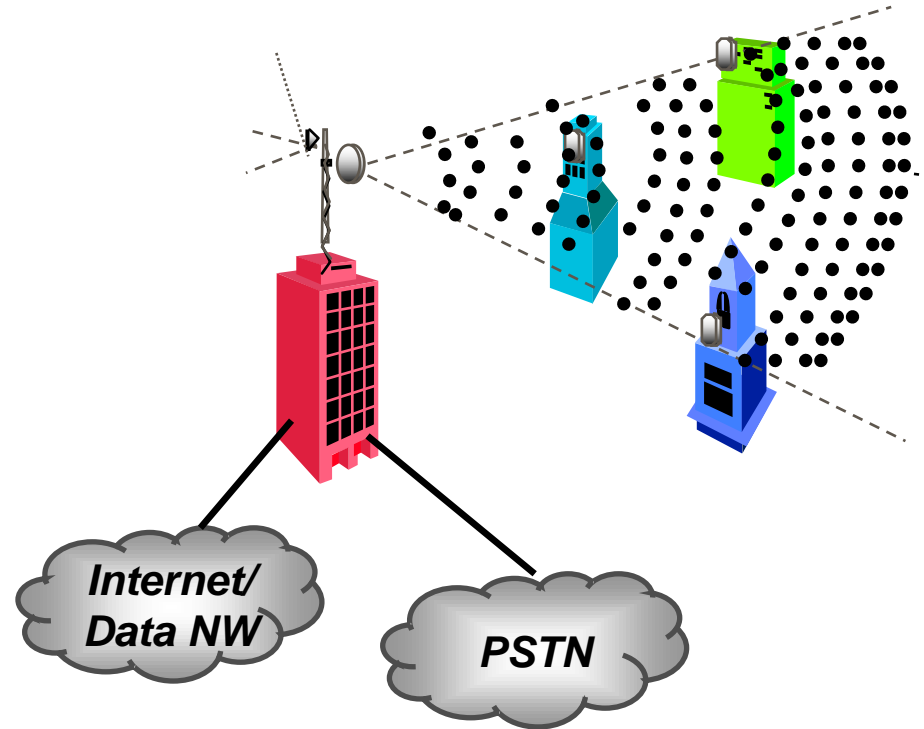


MMDS (II)

- Spectrum in the 2-3 GHz range
- High equipment cost
 - both provider and end-user install an antenna
- Suitable for rural areas, due to low deployment cost and large area coverage
- In general, limited commercial deployment
- In 2006, in USA, MMDS spectrum was auctioned for other applications
- Superseded by WiMaX

LMDS (I)

- **Local Multipoint Distribution Service** (a.k.a. wireless fiber-optic network)
 - Local: Cell range is 2.5-5 km
 - Multipoint: point-to-multipoint bidirectional connections
 - point-to-point is also feasible
- **Distribution Services:**
 - initially used as a substitute for cableTV/satellite
- Can also provide broadband point-to-point connectivity



LMDS (II)

- Spectrum in the 28-GHz and 31-GHz range
 - Higher capacity than MMDS (up to 155Mbps)
 - Line-Of-Sight only operation
- Was considered as a promising solution for **fixed** broadband wireless access
 - In Greece, 6 licences for spectrum bands where auctioned in December 2000
- In general, limited commercial success, due to
 - 1999 bubble
 - Progress and penetration of DSL, WiMax
 - Now, mostly used for point-to-point connections

WiFi (IEEE 802.11)

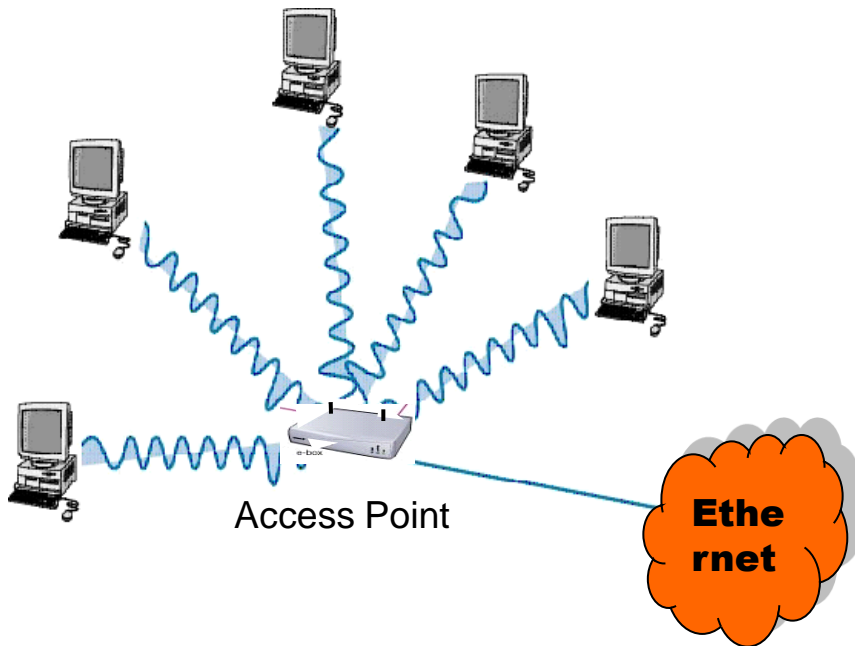
- WiFi: Wireless Fidelity
- An IEEE family of standards for Wireless LANs (WLANs). Usually used for:
 - Sharing access to Internet
 - Allowing nomadic mobility to working users
 - Avoid cabling
- Utilizes air frequencies for transmitting packets
 - Unlicensed band (2.4GHz)
 - Licensed band (5.4GHz)
 - The band used affects transmission rates and range
- No Line-of-Sight (LoS) requirement

WiFi sub-standards

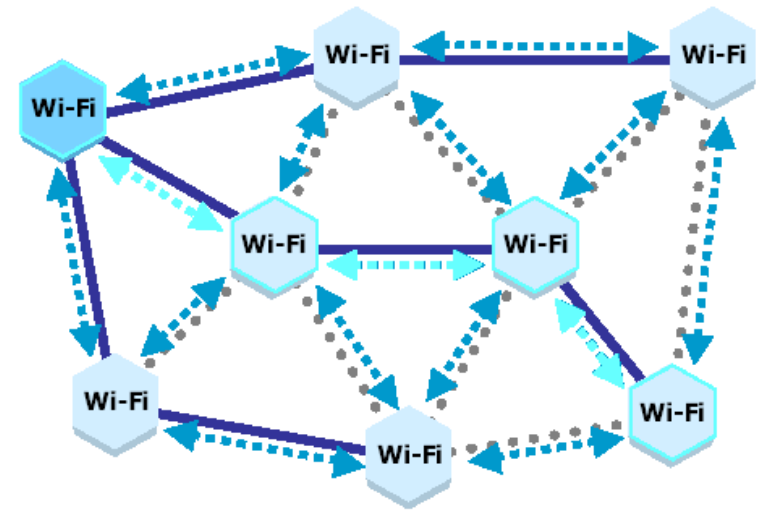
- 802.11a: Operates at 5 GHz
 - Theoretical rate: 54 Mbps
 - Low adoption rate, due to operation in licensed spectrum band
- 802.11b: Operates at 2.4 GHz
 - Theoretical rate: 11 Mbps
- 802.11g: Operates at 2.4 GHz
 - Theoretical rate: 54 Mbps
 - Compatible with 802.11b
 - WiFi cards are low-priced → high adoption rate
- 802.11e
 - Offers QoS capabilities: high and low priority data
- 802.11i
 - Improved security features (implemented on MAC layer)
- 802.11n
 - Will provide higher rates: Theoretical 600 Mbps!
 - Still under standardization, due to disputes
- 802.11r: Supports mobility and roaming

WiFi topologies

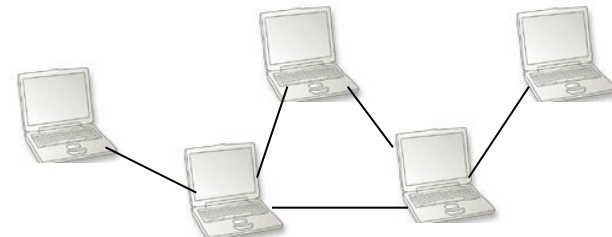
Infrastructure-based WLANs



Meshed / Peer-to-peer WLAN

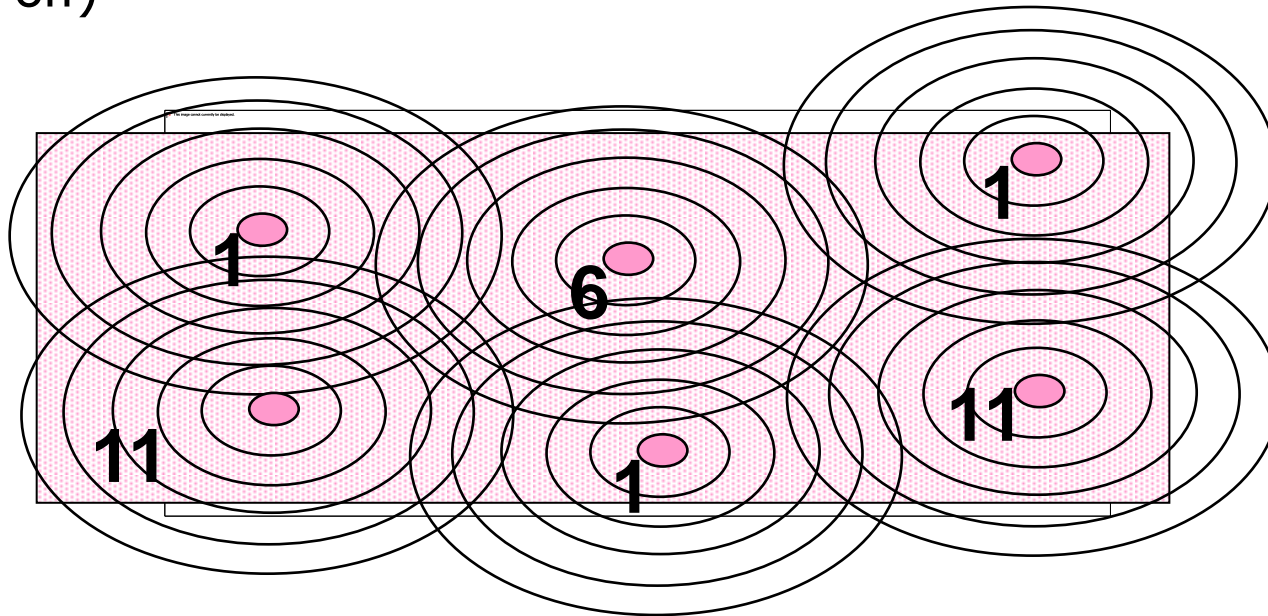


Ad Hoc WLAN



WiFi cells

- Every **access point** creates a WiFi cell
 - Channels range from: 1 to 11 (USA) or 13 (Europe) or 14 (Japan)
 - Coverage range depends on WiFi standard (order of 100 m)
- Users can roam between cells
 - 802.11r will define the transition process of a mobile client as it moves between access points (promises 50ms delay during hand-off)



WiFi Hotspots

- Private hotspots: intra-enterprise, home WLAN
- Public hotspots at popular places (airports, cafes,...) offered as a charged service → Typical scenario:
 - Range 20-75 m
 - ~15 users per Access Point *share* between. 1-11 Mbps
- Free hotspots
 - Open hotspots in neighborhood
 - Municipal wireless networks in several places in Attica
 - Central Athens www.athenswifi.gr
 - Piraeus Port WiFi (info.yen.gr/info/page_en.php?id=1200)
- Impact to OTE: Public/free hotspots steal some market share from DSL

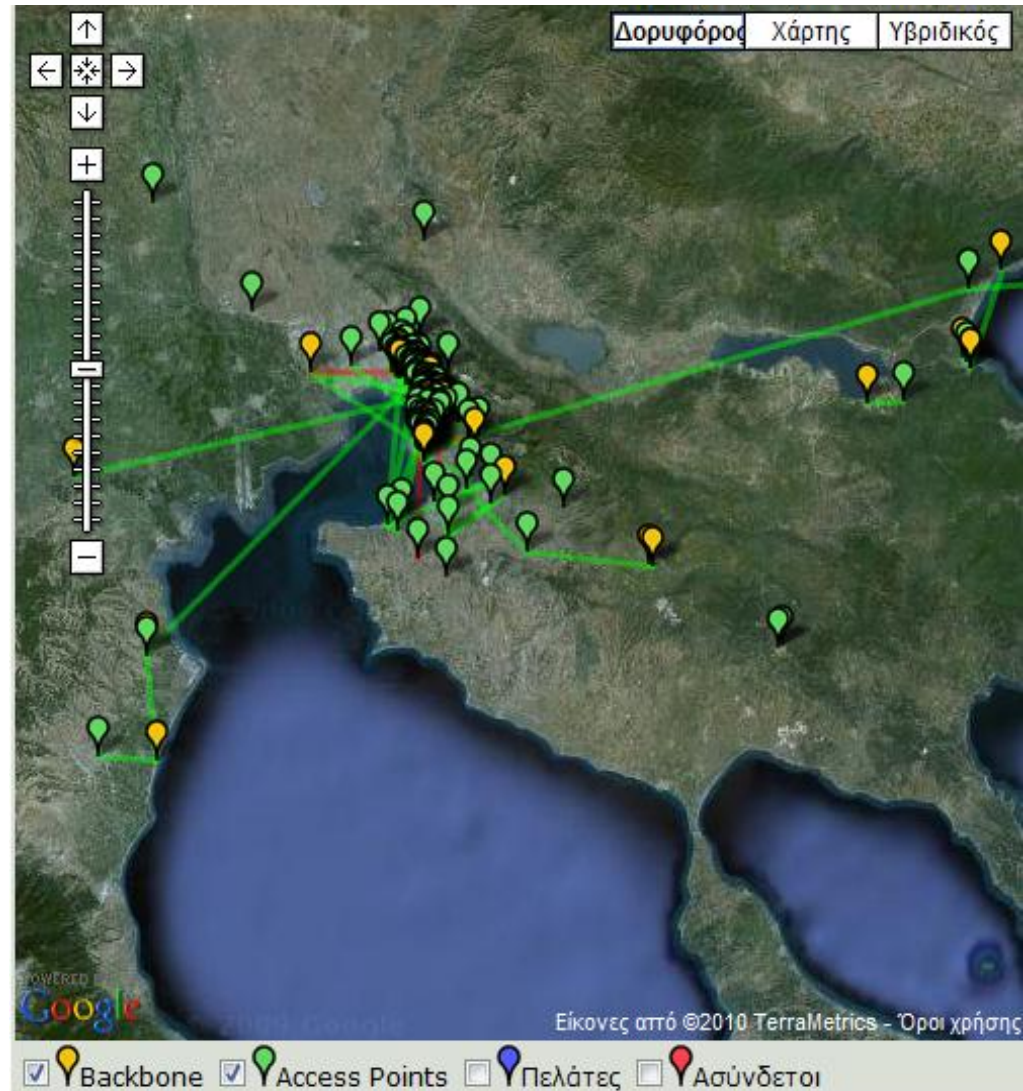
Athens Wireless Metropolitan Network

- Meshed topology
- www.awmn.net
- Since 2002
- 606 access points
- Expands continuously
- Covers a large portion of Attika



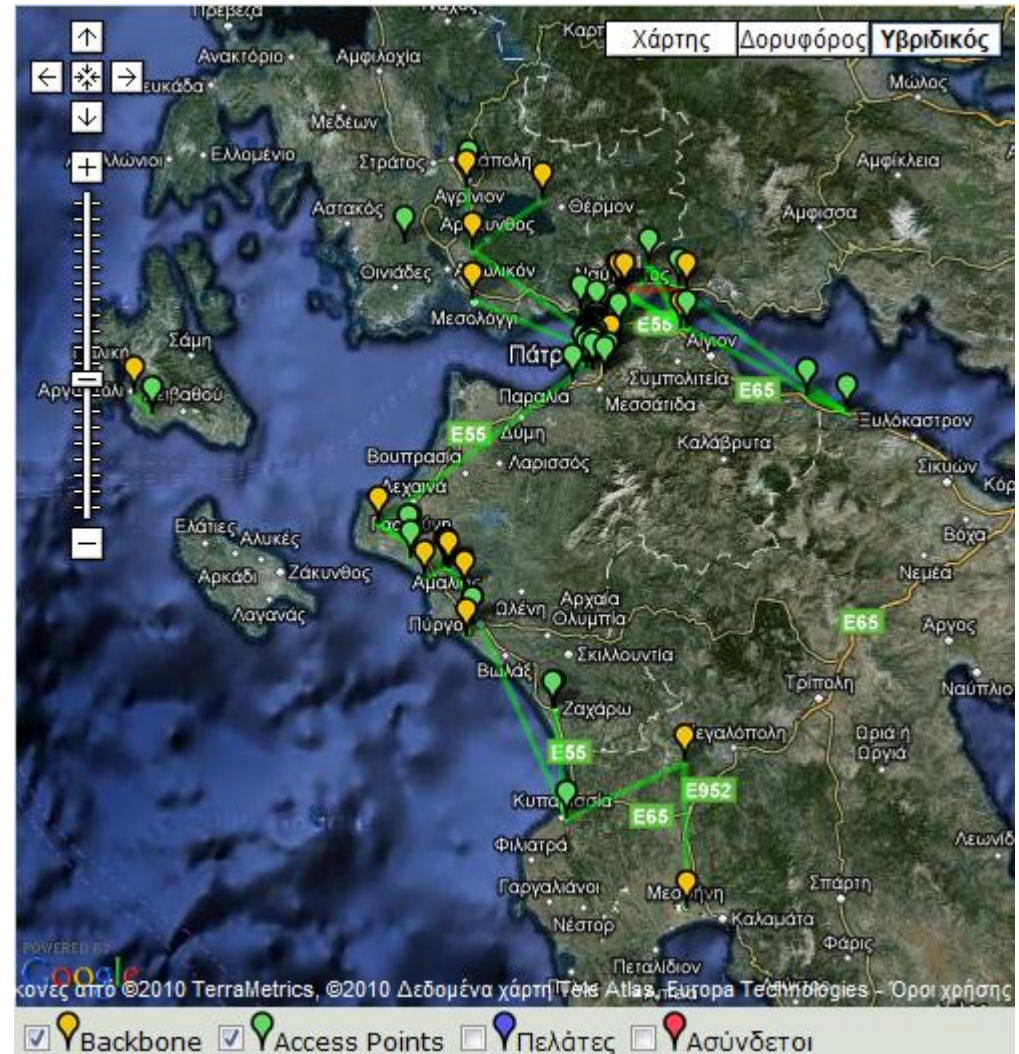
Thessaloniki's Wireless Metropolitan Network

- 1636 nodes
- 109 backbone κόμβοι
- 559 interconnections
- 110 access points
- 92 active services



Patra's Wireless Metropolitan Network

- 461 nodes
- 71 backbone κόμβοι
- 170 interconnections
- 62 access points
- 55 active services



WiMax (IEEE 802.16)

- WiMax → Worldwide Interoperability for Microwave Access
- An IEEE family of standards for:
 - creating Wide Area Networks (WANs)
 - providing wireless last-mile to:
 - fixed users
 - nomadic usersserving as a substitute of DSL
- Can operate in a wide frequency range: 2 - 66 GHz
 - Usually: 2.5 GHz (USA), 2.3 GHz and 3.5 GHz
→ Economies of scale in equipment production

WiMax (sub)standards

- IEEE 802.16c sub-standard
 - Frequency range is 10-66 GHz with LoS restrictions
 - Cell radius is 1-5 km miles
- IEEE 802.16a sub-standard
 - Frequency range is 2-11 GHz without LoS restrictions
 - Cell radius is 5-8 km
 - Max. range is 50 km with LoS restrictions
- IEEE 802.16d sub-standard
 - Quality-of-Service enabled
- IEEE 802.16e sub-standard
 - Provides mobility-roaming support,
 - Appropriate for real-time applications
 - Cell radius is 1-5 km
- IEEE 802.16m sub-standard
 - as 802.16e but higher rates & reduced latency
 - in progress

IEEE 802.16-2004
standard

Mobile-WiMax
No LoS

WiMAX System Type	Reach Capability	Max. Downlink Bandwidth Per Sector	Max. Uplink Bandwidth Per Sector	Downlink Bandwidth Per CPE At Cell Edge	Uplink Bandwidth Per CPE At Cell Edge
Standard					
LOS	10 – 16 km	8 – 11.3 Mbps	8 – 11.3 Mbps	2.8 – 11.3 Mbps	2.8 – 11.3 Mbps
NLOS	1 – 2 km 0.3 – 0.5 km (indoor self-install)	8 – 11.3 Mbps	8 – 11.3 Mbps	2.8 – 11.3 Mbps	2.8 – 11.3 Mbps
Full-Featured					
LOS	30 – 50 km	8 – 11.3 Mbps	8 – 11.3 Mbps	2.8 – 11.3 Mbps	2.8 – 11.3 Mbps
NLOS	4 – 9 km 1 – 2 km (indoor self-install)	8 – 11.3 Mbps	8 – 11.3 Mbps	2.8 – 11.3 Mbps	0.7 – 0.175* Mbps

*assumes only one subchannel is used to extend to edge of sector cell

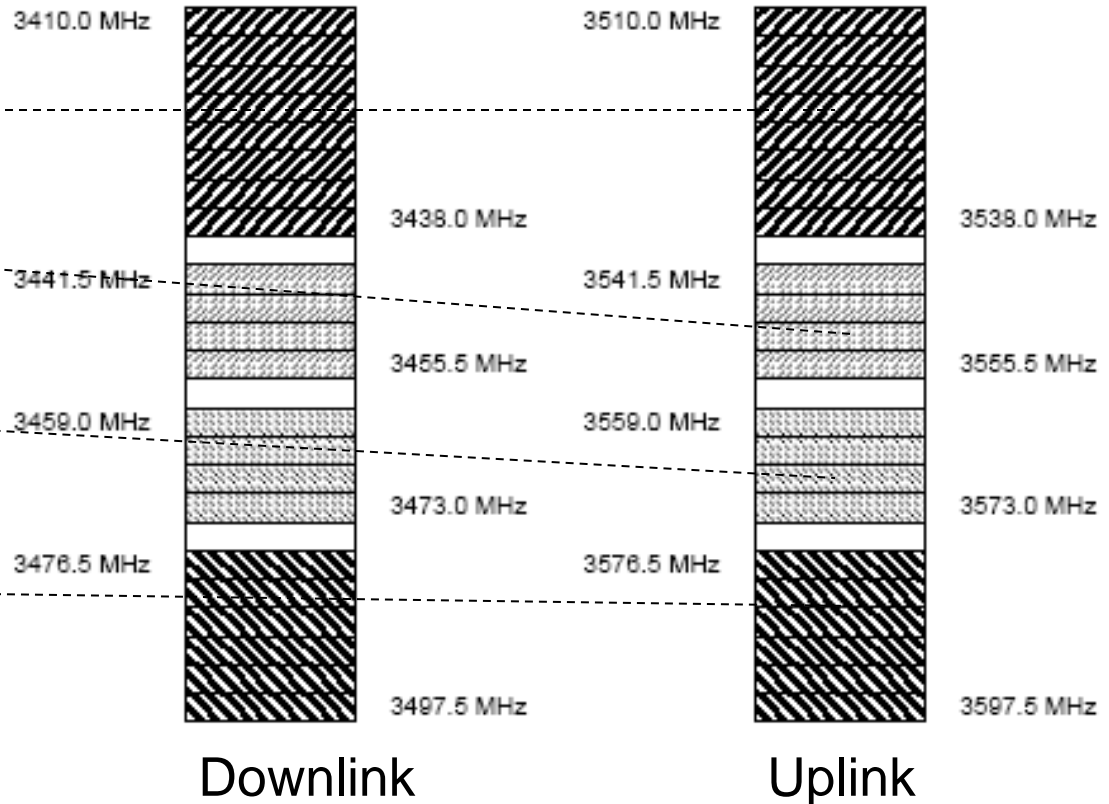
Source: © Corning

WiMax in Greece

- 4 licensed operators in Greece:

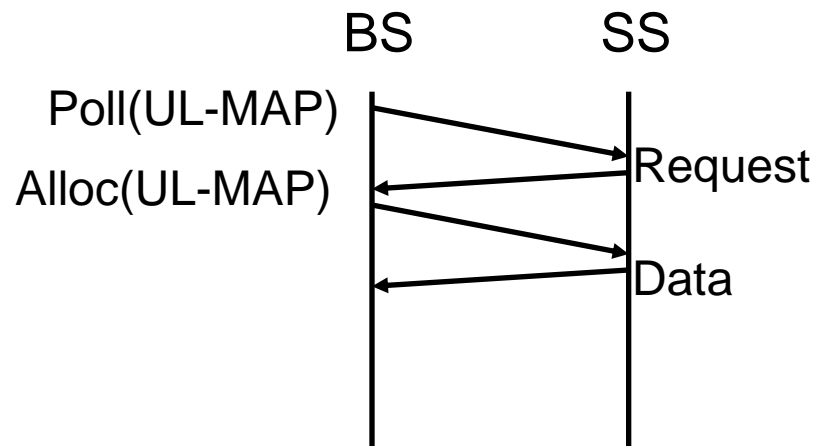
- Craig (since 2001)
 - Previously LMDS
- OTE (since 2000)
 - Previously LMDS
- COSMOLINE (July 2006)
 - for € 20.475M
- Q-Telecom
 - Previously LMDS

Wi-Max slots in 3.5 GHz Spectrum (EETT)



WiMax uplink sharing

- A Subscriber Station (SS) follows the Base Station (BS) instructions.
 - BS allocates space for the SS in the uplink subframe.
 - SS Requests service
 - BS allocates the requested space for the SS (if available).
 - Different QoS levels are possible
 - SS uses allocated space to send data.



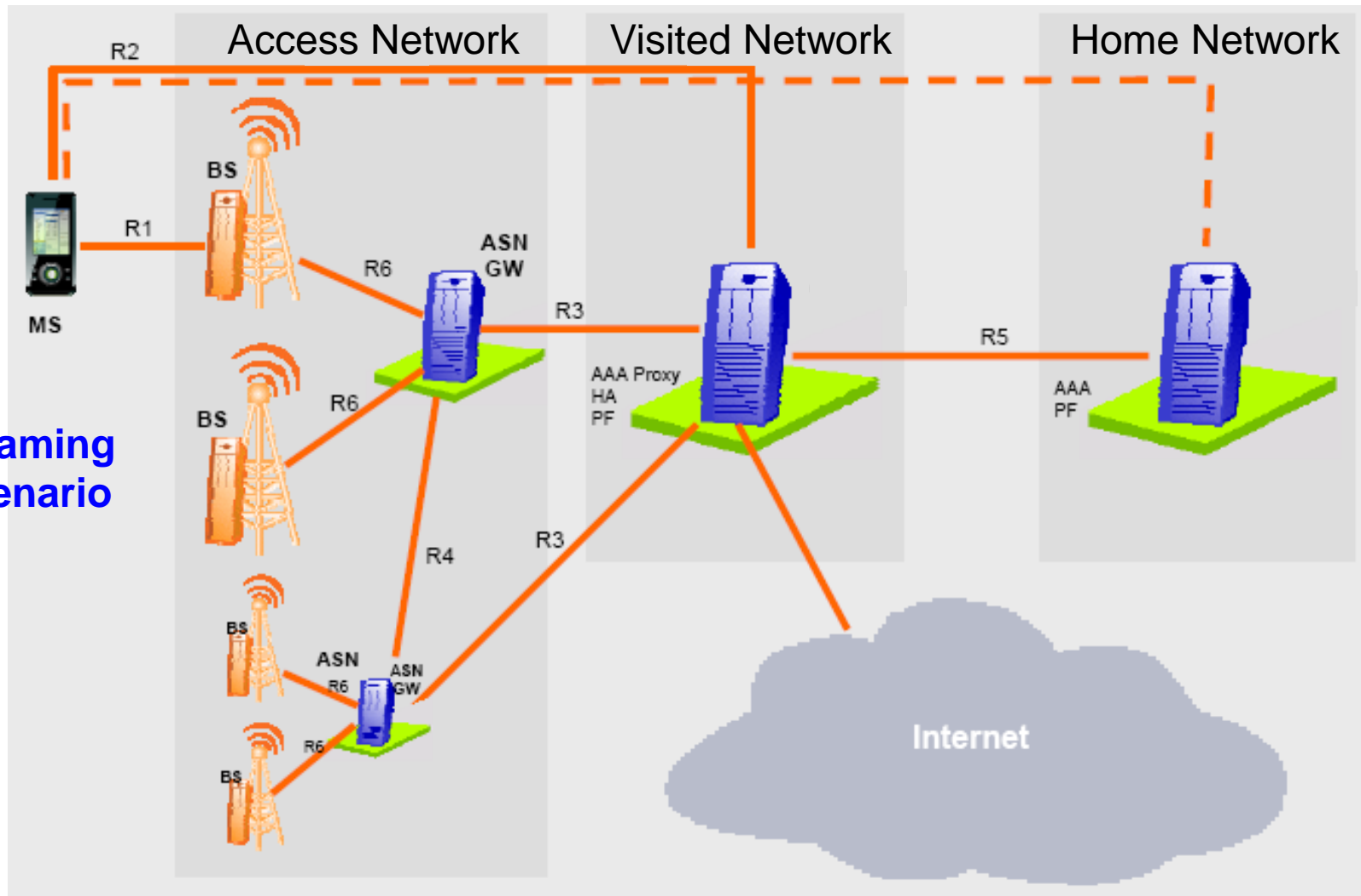
WiMax Scenarios

- Point-to-point with Line-Of-Sight (LoS)
 - Used for backbone connections
 - Transmission rate decreases as range increases
 - Highest data rate is 72 Mbps
 - Maximum range is 50Km
- Point-to-multipoint without LoS
 - End-user services
 - **BS multiplexes** the end-users' traffic as the **DSLAM** does in DSL



Mobile-WiMax Network Architecture

Roaming scenario



Most promising business cases for WiMax

1. Backhaul solution, alternative to leased lines
2. Fixed broadband wireless access solution for sparsely populated areas, where it is not cost-effective to install:
 - DSLAMs and backhaul for DSL
 - 3G
3. Complement to 3G, for more efficient utilization of spectrum:
 - Push video or other demanding traffic to less expensive WiMax

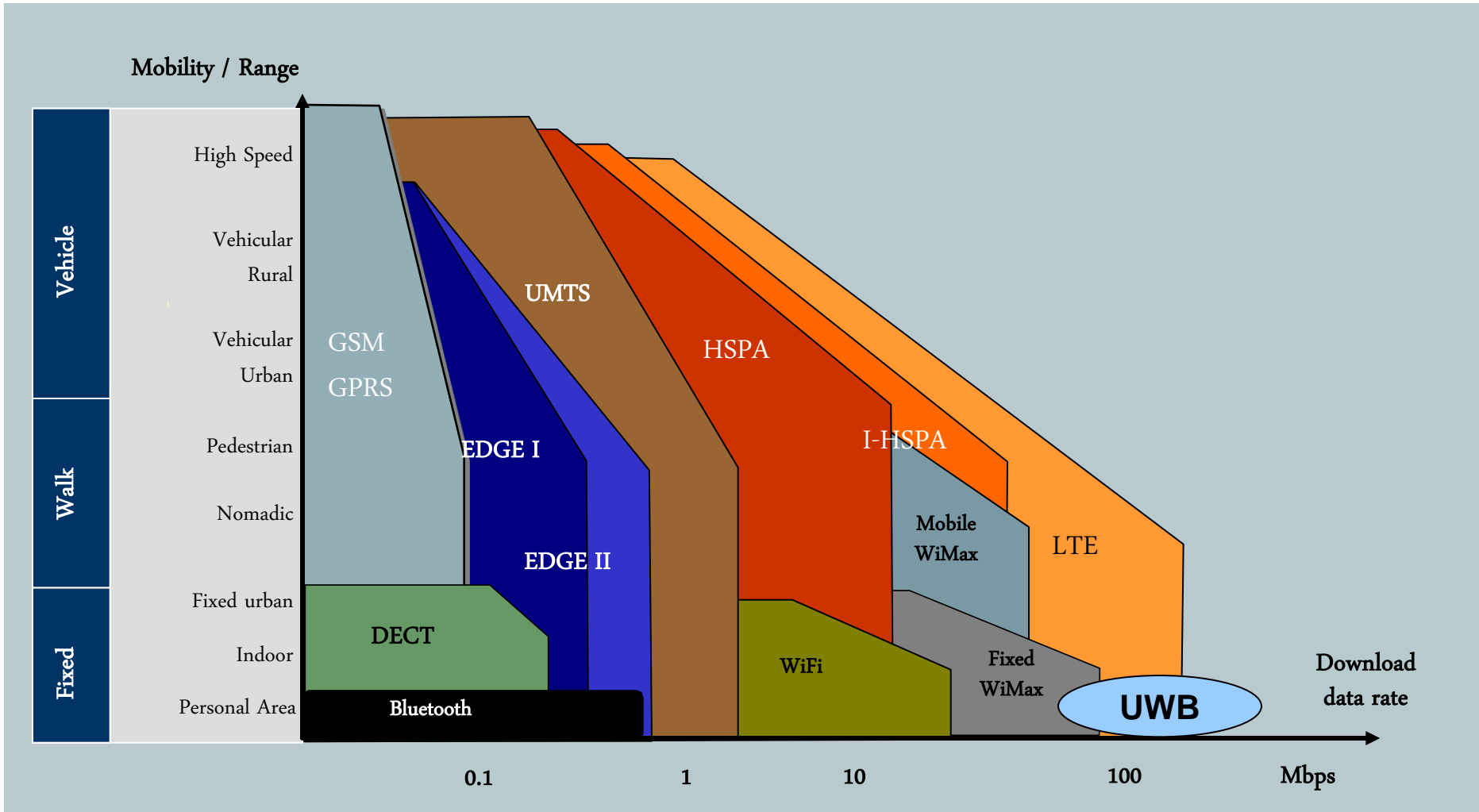
Most promising business cases for WiMax

- **Mobility** support will be a key issue for its future success, but requires
 - Effective support of roaming
 - Affordable customer's equipment
 - Additional spectrum:
 - possibly given after analogue TV switch-off
 - by changing the use of certain bands

Impact of WiMax to OTE

- May compete with DSL in both retail and wholesale markets
- May compete with broadband leased lines in the retail market, particularly in urban areas
- May compete with leased lines in the wholesale market:
 - Point-to-point WiMax vs connecting leased line segments
 - Point-to-multipoint WiMax vs terminal leased line segments

Wireless Technology Positioning



Mobile Wireless Access (I)

- Controlled by mobile operators
 - Oppose open access (full control of mobile devices)
 - Opposite to Internet culture!

2G

- GSM (Global System for Mobile Communications)
 - Rate 9.6kbps

2.5G

- GPRS (General Packet Radio Service)
 - Data over mobile telephony network
 - Based on packet rather than circuits (as GSM)
 - Theoretically up to 171.2kbps
 - Much lower rates in practice (32-40 kbps)
 - Large latency

From 3G to 4G

- 3G requirements were described by ITU under the term **IMT-2000**
 - access to a wide range of mobile telecommunication services;
 - compatibility of 3G with fixed networks (e.g. PSTN/ISDN/IP);
 - standardized design;
 - high quality;
 - worldwide roaming capability
 - Both UMTS and (more recently) Mobile-WiMax meet them
- 4G requirements (**IMT-Advanced**) are
 - True Mobile Broadband
 - 1Gbps peak data rate for fixed services
 - 100Mbps data rate for mobile services
 - High mobility to 500Km/H
 - **Access network agnostic**
 - **Flat All-IP network architecture**
 - Still in early phase and no technology is currently included (neither WiMax or LTE).

Mobile Wireless Access (II)

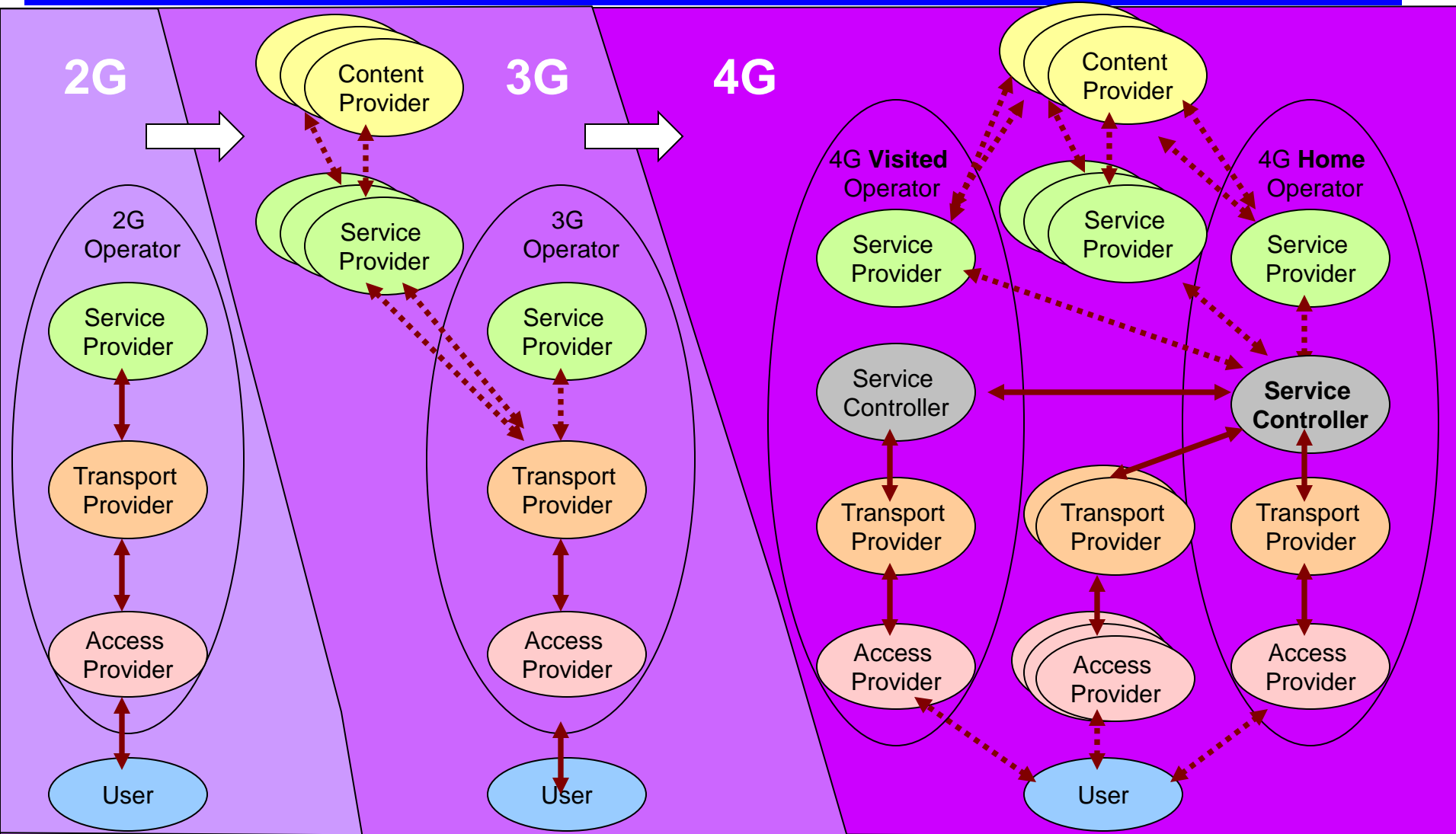
2.5G (continued)

- EDGE (Enhanced Data rates for Global Evolution) or EGPRS
 - Advanced version of GSM, supersedes GPRS
 - Serves voice and data in 384kbps → 1Mbps

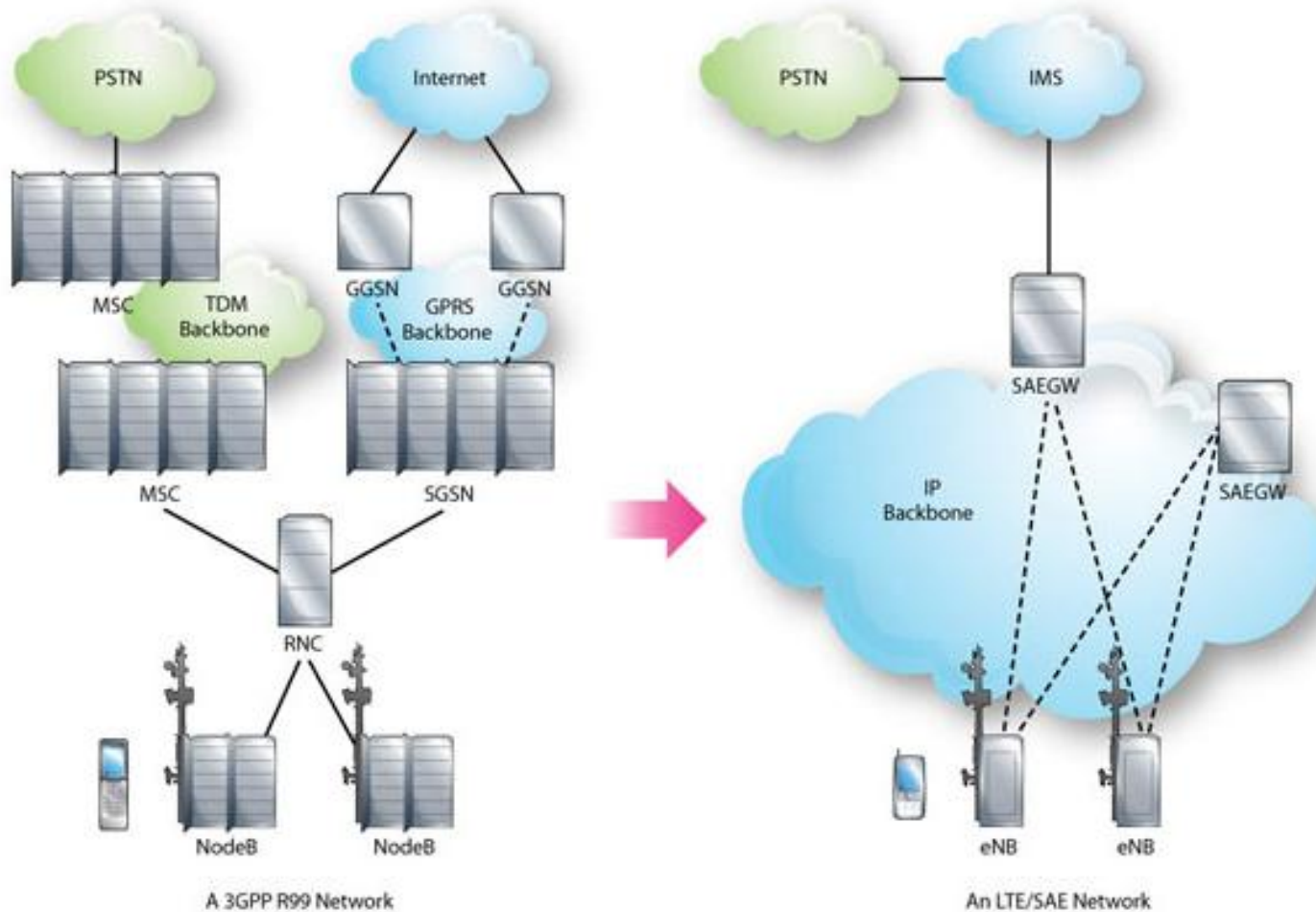
3G

- UMTS (Universal Mobile Telecom. System) or 3GSM
 - Theoretically up to 384kbps for heavy mobility
 - May reach 2Mbps in more stable environments
 - Supports video-calls and videoconferencing
 - Very expensive → low demand
- 3.5G HSDPA (High-Speed Uplink Packet Access) reaches 14.4 Mbps in the downlink

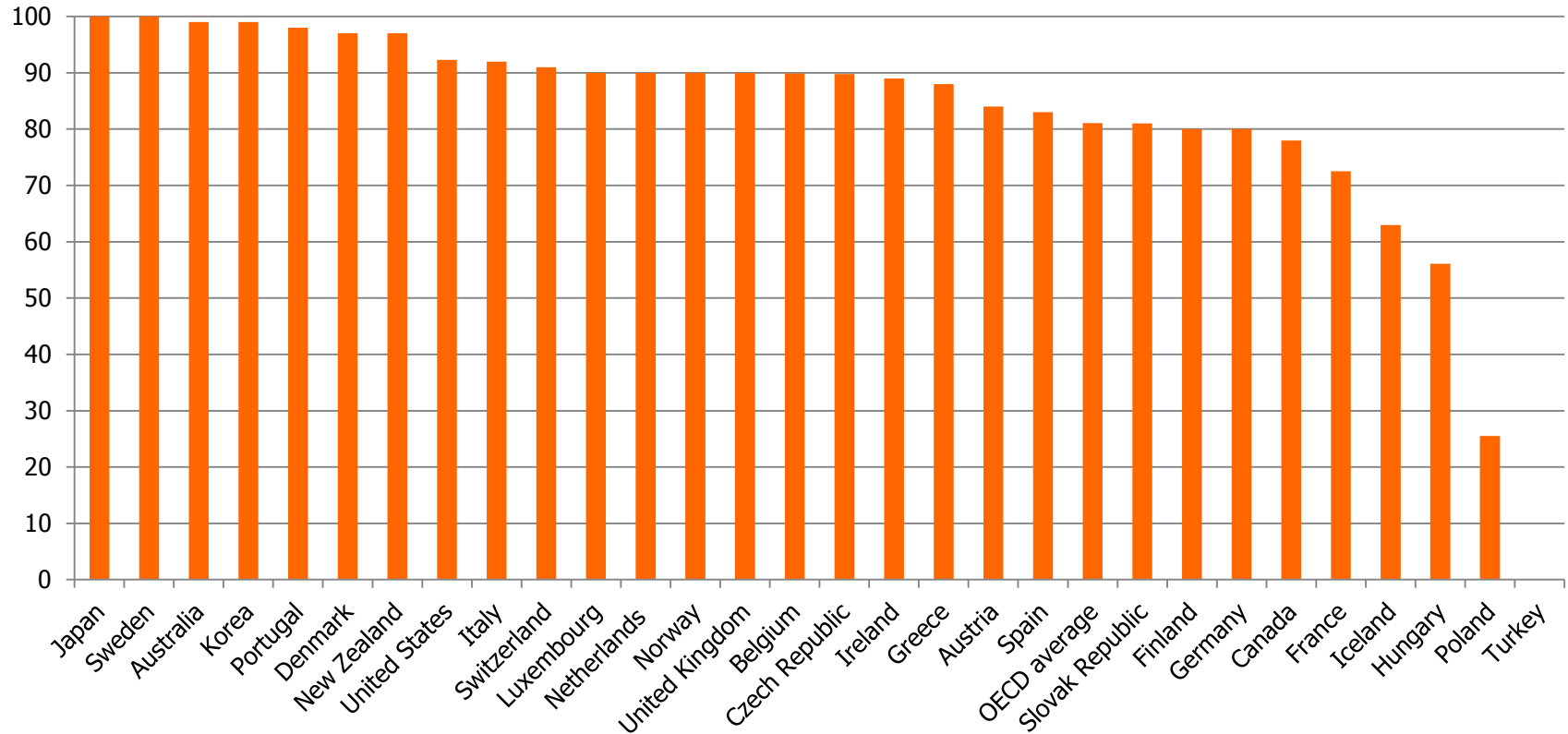
Mobile Value Chain Evolution



3GPP: From 3G to 4G



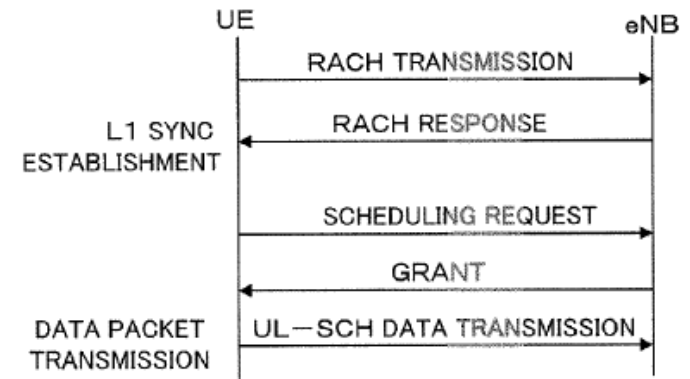
3G population coverage: up to 2009





LTE (Long Term Evolution)

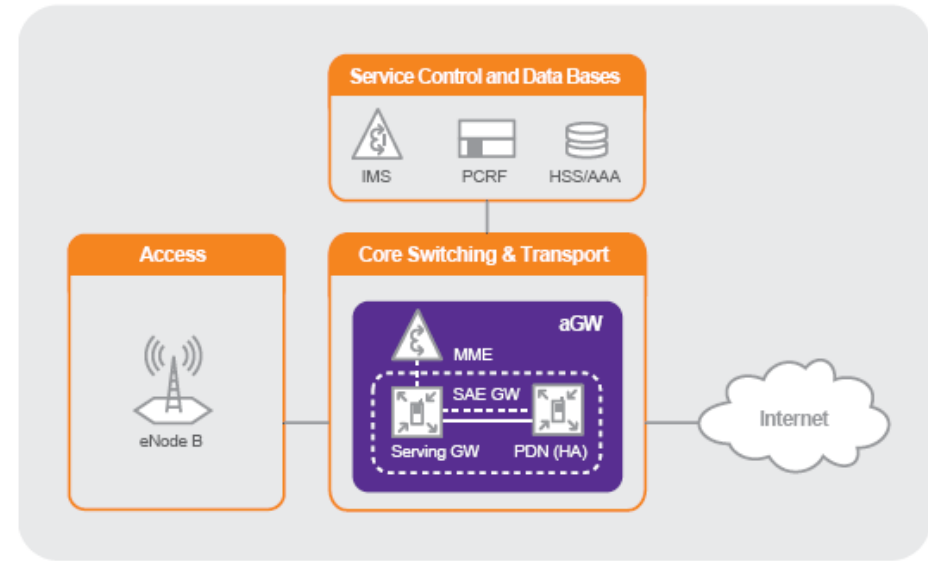
- Shared radio resource allocation scheme
 - Supports QoS
 - Uses MIMO antennas
 - Uses OFDMA for downlink
 - Uses Single Carrier Frequency Division Multiple Access (SC-FDMA) for uplink
 - better power efficiency than OFDMA
- Peak data rates per 20MHz of spectrum
 - Downlink: 300Mbps
 - Uplink data rates: 75 Mbps



SAE: System Architecture Evolution

aka EPC (Evolved Packet Core Network)

- The MME
 - Control plane functions related to subscriber and session management.
- The Serving Gateway
 - termination point of the packet data interface towards E-UTRAN.
- The PDN Gateway
 - termination point of the packet data interface towards the PDN (supports Policy Enforcement through PCRF)



MME = Mobility Management Entity

PDN = Packet Data Network

PCRF = Policy Charging Rules Function

**These roles may be supported
by a single node**

Mobile Broadband Market Trends

- Mobile WiMax (802.16e) has time advantage, since LTE/SAE is still in standardization phase
 - Sprint-Clearwire already offer mobile WiMax services (branded Xohm) in Baltimore
 - \$35/month for residential users
 - \$45/month for mobile users
 - However, WiMax devices are not yet widely available
- But, mobile operators' natural choice is LTE/SAE
 - Enables their "walled garden" business model
 - WiMax is well-suited for "open content" strategies, since it decouples SIP from basic connectivity service
 - Upgrade costs are important, but network management easier (know-how)
 - Verizon Wireless announced plans to roll out LTE/SAE-based services in 2010

} D/L: 4Mbps/ 2Mbps



Comparison of wireless technologies

	Cost	Data Rates	QoS	Security	License Required	Requirements
LMDS	Medium	Very High	Low	Low	Yes	LoS
Wi-Fi	Low	High	?	Medium	No	-
WiMax	Low	Very High	High	Medium	Yes/No	LoS Yes/No
UMTS	High	High	High	Medium	Yes	-
LTE/SAE	High	Very High	High	Medium	Yes	-
Satellite	Medium /Very High	Very High	High	High	Yes	LoS

Open vs closed access

- Traditionally mobile operator favour closed access
- Internet against Telecoms: WiMax, WiFi vs 3/4G
- USA: new 700MHz C-block comes with “open access” conditions (open to 3d party applications)
- Verizon won the auction (Google bided)
- New devices and applications provided they meet some minimum standards
- Google: pressure for releasing unused TV spectrum for Internet access (nationwide)
 - Android OS

Concluding remarks

- Wireless technologies progress very fast
 - Cellular moves towards broadband
 - Fixed wireless moves towards mobility
- Wide variety of technologies and features:
- 3G (HSDPA) and WiFi/WiMax are expected to be the winning combination for mobile broadband
- Higher bitrates are coming up, but this requires more spectrum
- According to ITU decisions, EETT has just started (March 2009) in Greece public consultation on possible new uses of some spectrum in the 2,6GHz band by IMT Technologies
 - IMT= International Mobile Telecommunications
 - includes WiMax

Concluding remarks (cont.)

- Mobile operators discover that the danger of being reduced to a dumb pipe!
 - WAN networking to laptops (3G, WiMax)
 - 27M mobile broadband users (2009)
 - Prices drop, networks are upgraded
 - **But loss of control!! Open Internet access!**
 - Congestion creeping in! DPI technology needed?
 - **Will mobile operators respect network neutrality?**
- Nomadic computing is taking off!
 - Laptops, smartphones: all that a nomad needs
 - Permanent connectivity, not motion, is critical